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XXV.—*On certain Points in the Morphology of the Blastoidæ, with Descriptions of some new Genera and Species.*
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In the following pages we give some zoological descriptions of certain new genera and species of Blastoids which have come under our notice during the preparation of our joint memoir on the group. We propose in this memoir to limit our zoological work to the British species* only, though this is by no means the case with our morphological researches. These have led us to establish three new genera for some very singular types, which are described in the following pages, as they do not occur in this country. Their morphology will be discussed in full in our larger work, with the aid of the beautiful figures which are being prepared by our friends Messrs. C. Berjeau and P. Highley.

* A revision by competent hands of the American species of Blastoidæ, like that of the Palæocrinoïdæ which is being so ably conducted by Messrs. Wachsmuth and Springer, is a very great desideratum. We have attempted in vain to work out the synonymy of many so-called species, owing to the want of material or of satisfactory descriptions and figures. The so-called *Codaster pulchellus* of Miller and Dyer (Journ. Cincinnati Soc. Nat. Hist. 1878, i. p. 35) is a case in point. There is no mention of hydrospiral slits in the specific diagnosis: nor are any shown in the figure; and we cannot help suspecting that this species represents a type very different from the original *Codaster* of McCoy.

The basis of the classification which we have been led to adopt is the morphology of the hydrospires and of their external openings, the so-called spiracles. We find that the structure and distribution of these organs, together with the arrangement of the various elements composing the ambulacra, present characters of much systematic value.

Besides discovering various new generic types, both British and foreign, we have been led to form entirely new conceptions of some of the already existing genera, e. g. *Orophocrinus* (*Codonites*) and *Granatocrinus*; while we are able to give more precise definitions of *Troostocrinus* and of *Tricelocrinus* than have hitherto been attempted.

In order to facilitate the comprehension of our specific descriptions, we give the following explanation of our terminology:—

The plates forming the calyx are the basals, radials or fork-pieces, and the deltoid pieces or orals*.

In *Codaster trilobatus* and in the more flat-topped American species of the genus the middle line of each oral is occupied by a more or less strongly marked ridge, the *oral ridge*. But in other species of *Codaster* and in the allied genus *Platynoschisma* this ridge is represented merely by an edge, from which the sides of the orals slope sharply downwards towards the ambulacra. This oral ridge is often very prominent at the central ends of the oral plates of *Pentremites*, so as more or less completely to separate the proximal ends of the passages which lead to the hydrospires of adjacent ambulacra.

In most Blastoids each radial is more or less fork-shaped, the handle of the fork being the *body* of the radial (which is separated from the basals by the *basiradial suture*), while the two prongs are the *limbs*. Between them is the *radial sinus*, which is occupied by the ambulacrum. This terminates in a more or less prominent "*lip*" on the upper edge of the body of the radial †.

Of the ambulacral structures which together fill up the

* As far as we can judge from various passages on pp. 12 and 13 of the 'Revision of the Palæocrinoidea' by Messrs. Wachsmuth and Springer, these authors seem to hold the same view as we do respecting the homology of the deltoid plates of the Blastoids with the "consolidating plates" of *Cyathocrinus* and the orals of the Pentacrinoid. But they make no definite statement to this effect.

† According to Messrs. Wachsmuth and Springer, "The lower part of the forked plate leading to the ambulacrum is the first radial—in *Blastoidocrinus*, the oldest Blastoid, the suture is visible—and the two sides of the fork, instead of being interradial, form together a second radial" (Revision, p. 12). We are sorry that we cannot agree with the American palæontologists in this view. We have unfortunately been unable to

radial sinus to a greater or less extent, the most important is the lancet-plate, which is excavated lengthways by the food-groove or ambulacrum proper. Upon or against it rest the *side plates* (pore-plates, *litt.*), which thus conceal it more or less completely; they are marked by minute pits, from which delicate grooves slant outwards towards the marginal pores. The latter are unconnected with the pinnules, which are arranged in a single or double row at the sides of the ambulacra. Their bases are apparently inserted into the above-mentioned pits or *pinnule-sockets*. In many species the distal edge of each pore is bounded by an *outer side plate* (supplemental pore-plate, *litt.*).

Between and more or less beneath the ambulacral fields are the interradial systems of lamellar tubes or *hydrospires*. The openings of these tubes directly on the ventral surface of the calyx, as in *Codaster* and *Phenoschisma*, are the *hydrospire-slits*. When these organs are concentrated beneath the ambulacra, the gap between the edge of the lancet-plate and the sides of the radial sinus is the *hydrospire-cleft*; it leads downwards into the *hydrospire-canal*, into which the hydrospires open by their slit-like upper ends. The hydrospire-cleft is much reduced and somewhat modified in the American species of *Orophocrinus*, but is widely open in the European species, especially in the Belgian ones, so as to expose some of the hydrospire-slits. In *Pentremites* proper it is also wide, but is bridged over by the side plates, between which are the *hydrospire-pores*. In *Granatocrinus* and *Schizoblastus* the inner wall of each hydrospire, *i. e.* that nearest the median line of the ambulacrum, is often carried upwards in certain parts of the ambulacra towards the ventral surface. Here it appears as a narrow plate-like edge between the lancet-plate and the side of the radial sinus. We have seen this *hydrospire-plate* very distinctly in *Schizoblastus melo* and in some of the British species of *Granatocrinus* (*G. ellipticus*, *G. derbiensis*). It bears a number of lateral processes, which meet corresponding ones upon the sides of the radial sinus, so that the hydrospire-cleft is represented merely by a row of pores alternating with

examine any specimens of *Blastoidocrinus*, which we only know from the figures of Billings and Schmidt. But we imagine the suture referred to by Wachsmuth and Springer to be the suture between the radials and orals (*oro-radial*), just as is shown in the hypothetical figure given by Billings ('Canadian Decades,' iv. p. 20), in whose interpretation of the calyx we entirely concur.

The form of the radials in the Mesozoic *Phyllocrinus* also indicates clearly that the fork-pieces of the Blastoids are *præ*teritively simple and undivided.

these processes. The hydrospire-pores, therefore, are formed without the intervention of any "pore-plates," which, for this and other reasons, we prefer to call "side plates."

The hydrospire-canal opens externally by the *spiracles*, which are arranged at the summit, round the peristome; they may be either single (*Granatocrinus*) or paired (*Schizoblastus*, *Troostocrinus*). The spiracle or spiracles of the anal inter-radius may be confluent with the anal opening to form the *anal spiracle*.

In the better-preserved examples of many American Blastoids the mouth and peristome are concealed beneath a vault of minute irregular *summit-plates*, any definite arrangement of which is rarely traceable. This vault is sometimes continued down the ambulacra by a series of tiny *covering-plates*, which close in the food-grooves completely and convert them into tunnels just as in recent Crinoids. In none of the European Blastoids that we have seen has any indication of these structures been preserved.

As some considerable time must still elapse before the publication of our memoir, we wish to direct the attention of our fellow workers to one or two morphological points of interest.

In the ordinary *Pentremites* the hydrospiral tubes beneath the ambulacra extend along the entire length of the radial sinuses and communicate with the exterior by the marginal pores; but in the little *P. conoideus*, Hall, and *P. Koninckianus*, Hall, of the Warsaw limestone*, the hydrospiral tubes appear to be absent from the terminal third of the ambulacra. The sinus is considerably shorter on the inner than on the outer aspect of the radial; and the hydrospiral tubes end abruptly on the inner face of the plate, while the ambulacra extend much further towards the base of the calyx. Examples of both species are common with the shell filled up by a foraminiferal matrix, which thus forms a complete cast of its interior. This may be readily exposed by the removal of the shell; and it is then seen that the length of the ambulacra externally is greater than that of their internal casts. We have been unable to detect this peculiarity in any other species of *Pentremites*, but we think it very probable that our American colleagues may be more fortunate. Sections through the upper part of the calyx of *P. conoideus* show that it possesses hydrospires constructed on the ordinary *Pentremites* type. We have not, however, been able to obtain thoroughly satisfactory sections through the distal portions of the ambulacra; but from

* We cannot help suspecting the identity of these two so-called species.

what we have seen we think it possible that the hydrospiral tubes may be continued onto the ends of the ambulacra actually within the substance of the radial plates. This is at any rate the case throughout the greater part of the length of the ambulacra of *Tricalocrinus*, as we have found from sections of *T. Woodmani*, and from the examination of some large isolated radials which may, we think, possibly belong to *T. obliquatus*, Römer, sp. We take this species to be an entirely different one from that which was described later by Meek and Worthen under the same name.

Some valuable observations have been recently made by Messrs. Wachsmuth and Springer*, and by Dr. Hambach†, on the structure of the ambulacra of the Blastoids. This is more especially the case with regard to the subambulacral canals, which were first discovered by Rofe in *Granatocrinus ellipticus*, although their true nature was misinterpreted by him; for he believed the lancet-plate of this type (then referred to *Pentremites*) to consist of two lateral halves. As Hambach has pointed out with respect to other species, this does sometimes appear to be the case in worn specimens; for when the superficial portion of an ambulacrum has been removed the canal within the lancet-piece (which was seen, though misinterpreted, by Rofe) is not unfrequently exposed.

We have had the advantage of examining the whole of Mr. Rofe's collection, together with many specimens of *Granatocrinus Norwoodi*; and we are convinced that in *Granatocrinus*, as we define the genus‡, there is but one subambulacral plate, the lancet-plate, which is pierced by a longitudinal canal. Messrs. Wachsmuth and Springer§, however, have described and figured the lancet-plate of *Pentremites* as imperforate, but as resting on an underlancet-plate which encloses a canal. Hambach||, on the other hand, describes the lancet-plate of typical *Pentremites* (*P. florealis*, *P. sulcatus*, *P. pyriformis*, &c.) as "pierced through the centre, in its whole length, by a very fine canal;" and we are inclined to think that he is right.

For although we agree with Wachsmuth and Springer in finding two subambulacral pieces in *Pentremites*, it seems to us more probable that the canal should be in the upper or lancet-

* "Revision of the Palæocrinoidea.—Parts i., ii.," Proc. Philad. Acad. 1879, 1881.

† "Contributions to the Anatomy of the Genus *Pentremites*, with Descriptions of new Species," Trans. St. Louis Acad. vol. iv. no. 1, pp. 145-160.

‡ See *postea*.

§ Revision, part i. pl. iii. fig. 5.

|| *Loc. cit.* p. 149.

piece than in the lower and much thinner underlancet-piece, which we have also found in *Orophocrinus* (*Codonites*). The former corresponds to the perforate lancet-plate of *Granato-crinus*, which is the only subambulacral plate figured by Wachsmuth and Springer in *G. Norwoodi*; so that in this respect our observations appear to be in accordance with theirs.

According to Hambach* there is also "a longitudinal duct or vessel resting in the concave furrow of (*i. e.* beneath) the lancet-piece, and running from the apex of the ambulacral field to the summit, where it connects with a circular duct (œsophageal ring?) surrounding, on the interior side, the central orifice or *annulus centralis*."

But no mention is made by Hambach of the particular species in which this second canal occurs—though, so far as we can judge from the figure to which he refers in connexion with the above passage, he appears to be speaking of a *Pentremites*. In this case he must have seen canals both in the lancet-plate and in the underlancet-plate of this type; while Wachsmuth and Springer have only seen the latter, and we have only been able to make out the former, *viz.* that within the lancet-plate.

We believe it to have lodged the radial water-vessel. In *Pentremites* and *Orophocrinus*, which have two subambulacral plates, there is an opening at the proximal end of each ambulacrum, between the edges of two adjacent oral plates and the end of the underlancet-piece. It was first discovered and figured in *Pentremites* by Wachsmuth and Springer†, whose observations we are glad to be able to confirm. In *Granato-crinus* its distal side is incomplete, owing to the absence of an underlancet-piece. The vessel contained in the canal within the lancet-plate passed downwards through this opening on its way to join an oral ring. By careful grinding down of the summit of well-preserved specimens we have been able to demonstrate the presence of this organ and its connexion with the canals within the lancet-plates in the following species—*Pentremites pyriformis* and *P. burlingtonensis*, *Granato-crinus Norwoodi* and *G. ellipticus*, *Schizoblastus Sayi*, *Pentremitidea d'Archiaci*, *Orophocrinus inflatus* and *O. stelliformis*, and *Codaster trilobatus*. We venture to think that there can be but little doubt as to its being the water-vascular ring; but we cannot say whether it is identical with the "circular duct (œsophageal ring?)" described by Hambach ‡, as his state-

* *Loc. cit.* p. 151.

† *Loc. cit.* p. 151.

‡ Revision, part i. pl. iii. fig. 4.

ments about it are somewhat obscure. He says that he has been so fortunate as to obtain this structure entirely from a well-preserved specimen of *Pentremites* (i. e. *Granatocrinus*) *Norwoodi*, but that it is connected with the longitudinal duct or vessel beneath the lancet-piece. As, however, no second subambulacral canal has been detected in this species either by Messrs. Wachsmuth and Springer or by ourselves, we cannot help suspecting that Dr. Hambach must have seen the "longitudinal duct" in a *Pentremites* and the "circular duct" in *Granatocrinus Norwoodi*; but, in default of further information, we cannot absolutely identify this "circular duct" with the oral ring described above.

Messrs. Wachsmuth and Springer* have suggested that "the passage directly beneath the (ambulacral) field is probably the dorsal or axial canal (i. e. of the Crinoid arm), which by the inverted position of the arms became the inner instead of the outer passage." We are not sure that we quite understand Mr. Wachsmuth's theory of the ambulacra of the Blastoids. If they represent the inverted arms of a Crinoid, surely the food-grooves ought to be internal and not external. But if by this and similar expressions Mr. Wachsmuth means to describe a Blastoid ambulacrum as a Crinoid arm partially bent upon itself, we are disposed to agree with him.

It is probable enough that the Blastoids possessed a chambered organ and axial cords radiating from it, as in the Crinoids; but we do not think that these cords were lodged within the lancet-plates or underlancet-plates of the ambulacra, as supposed by Wachsmuth and Springer.

We propose to limit the name *Pentremites* to those Blastoids which resemble *P. Godoni*, Defr., *P. sulcatus*, Römer, and *P. pyriformis*, Say, in their structure and general appearance. The ambulacra are broad and petaloid; and in most species the side plates merely rest against the edges of the lancet-plate, without covering any part of it. The central end of each oral plate is flat and laterally expanded, with a more or less marked oral ridge in the middle line that divides it into two lateral halves. Each arm forms the floor of a passage leading along the lower part of the radial sinus over the upper ends of the hydrospire-slits. It is converted into a canal (the hydrospire-canal) by the side plates, which are wedged in between the lancet-plate and the side of the radial sinus. Those nearest the centre may either meet one another over the

* Revision, part ii, p. 33 (207).

oral ridge or abut against its sides. So far as we are able to judge from the material at our disposal, the American species of *Pentremites* are all similar to *P. Godoni*, and readily recognizable as belonging to this generic type as defined above. In 1857 Mr. Sydney S. Lyon* announced the discovery in certain species of *Pentremites* of three small pieces situated below the basals, which he considered to represent the true basals; and he emended the formula of the genus accordingly. This view was afterwards supported in part by Messrs. Meek and Worthen†, who bore out Lyon's statement as to the presence of a dicyclic base in the calyx of *Pentremites*, but regarded the lower series as supplementary basals rather than as true basals.

We have given great attention to this important question, and must confess that up to the present time we have quite failed to detect any plates which could be regarded either as supplemental or as under basals. We cannot help thinking that the plates so regarded are nothing more than the uppermost stem-joint more or less modified. Indeed it appears to us that Messrs. Meek and Worthen were themselves not altogether clear on the subject; for in the description of their figures of *Orophocrinus* (*Codonites*) *stelliformis*, O. & S., they say:—"Fig. 5, a. A side view of a small specimen, showing the part under the base that has been, by some, supposed to be in the *Pentremites* the true basal pieces, to be really only some six of the upper joints of the column, ankylosed together and to the base" †.

In the meantime we wish it to be distinctly understood that we do not commit ourselves to either view, but leave the question an open one for further consideration and investigation.

Genus PENTREMITIDEA, d'Orbigny, 1849
(emend. E & C. 1882.)

Pentremitidea, d'Orbigny, Prodrôme de Pal. 1849, i. p. 102.

Pentremitidæa, d'Orbigny, Cours Élémentaire, &c. p. 139.

Gen. char. Calyx varying in outline from elongately clavate-pyramidal to pentagonal obpyriform; summit truncate or convex; base usually long and conical. Number and disposition of the plates similar to those of *Pentremites* proper, but the orals inconspicuous, confined to the summit, and never visible in a side view; radial plates always strongly lobate.

* D. D. Owen's 3rd Report Geol. Survey, Kentucky, 1857, p. 468.

† Illinois Geol. Survey Report, 1873, v. p. 464 (note).

‡ *Loc. cit.* v. expl. of pl. ix. fig. 5.

Ambulacra narrow in all but one species, not greatly depressed within the radial sinuses. Side plates lying actually on the lancet-plate, and usually hiding it from view. Spiracles usually large, and, as well as the hydrospires, constructed like those of *Pentremites*. Anal aperture confluent with the two spiracles at its sides, to form a common anal spiracle.

Obs. The name *Pentremitidea** was proposed by D'Orbigny in 1849 for two Devonian Blastoids from Spain, which he believed to be peculiar in having a calyx composed of but two rows of plates, the basals and radials. Römer† showed, however, that the two species in question, *P. Pailletti*, d'A. & de Vern., and *P. Schultzii*, d'A. & de Vern., are provided, like other Blastoids, with the third row of plates or orals. On these grounds, therefore, *Pentremitidea* has not been adopted by later writers on this interesting class. It appears, however, that *P. Pailletti*, in common with a limited number of other forms, possesses peculiarities of calicular structure which separate it at once from *Pentremites* as understood by us; and we propose, in consequence, to rehabilitate d'Orbigny's name for such species.

It may be contended that an entirely new name would have been preferable in this case. From the fact, however, that d'Orbigny's types, although unknown to him, happen to possess the chief points of structure on which we propose to separate the genus from *Pentremites*, we prefer to adopt his name rather than unnecessarily burden science with a new one.

Pentremitidea has a more slender and elongate calyx than *Pentremites*, or else one approaching in outline to that of *Orophocrinus*. These apparently dissimilar forms possess, in common, a slender base, narrow ambulacra, and oral plates entirely limited to the summit. The side plates of the ambulacra lie directly on, and in a great measure cover, the lancet-plates, except in one species. Such characters are diametrically opposed to those of *Pentremites*, when restricted (as we

* It may be well to state here that, in a paper read at the York meeting of the British Association in September 1881, one of us referred to the genus *Pentremitidea* and to *P. Pailletti* as having the hydrospiral slits more or less concealed by the ambulacra, but partially visible at their sides. We have since found, however, that a species presenting these characters (which will be described under the generic name *Phenoschisma*) has been hitherto confounded with the true *Pentremitidea Pailletti*, from the same locality, which it somewhat closely resembles in external form.

This fact seems to have escaped the notice of the donors of these fossils to the national collection, both types sharing in a common label—"*Pentremitidea Pailletti*."

† 'Monographie der Blastoideen,' Berlin, 1852, p. 49.

propose that this name should be) to such species as *P. Godoni*, DeFrance, sp., *P. sulcatus*, Römer, and *P. pyriformis*, Say, &c.

The variability of external form is perhaps as marked in this genus as in any member of the Blastoidea. Two distinct types are met with, the pyriform and clavate. Starting with the type species, *P. Pailletti*, representing the former, we have in the one direction a gradual transition through *P. lusitanica* to the much more elongated calyx of *P. Schultzii*, with its truncated summit and expanded ambulacra. In the other direction we observe a gradual change in outline through *P. eifelensis* to *P. clavata* and *P. acutangula*, and so on to the Orophocerinoid species *P. angulata* and *P. similis*.

The amount of truncation of the summit also varies considerably. In *P. Schultzii* we see the limit of variability, the summit being broad, flattened, and extending across the whole width of the calyx. The width of the summit is decidedly less in *P. Pailletti*, again smaller in *P. lusitanica*, and still more so in the aberrant *P. angulata* and *P. similis*. Similarly, the broader the summit the wider the ambulacra; hence we meet with the greatest development of this kind in *P. Schultzii*, the ambulacra gradually becoming narrower in *P. lusitanica* and *P. Pailletti*, and reaching the limit in the same two forms mentioned above.

As regards the more intimate structure of the ambulacra, we may describe three examples. In the first of these, *P. Schultzii*, the ambulacra are very wide, flattened, or a little concave, and more or less deltoid in form. The lancet-plate elongately petaloid, more markedly so than in most Blastoids. The side plates abutting against it are fourteen on each side, narrow, and oblong. The outer side plates are very small, placed quite at the extremities of the side plates, and nearly on the same level with them. In the clavate and pyriform types the structure is more or less similar, as, for instance, in *P. clavata* and *P. lusitanica*. The side plates do not reach the edges of the radial forks; but the intervening spaces are bridged over by the outer side plates, alternating with the pores, which are very large.

We are acquainted with the hydrospires of only two species, *P. Schultzii* and *P. Pailletti*, in both of which these organs are eight in number on each side of the ambulacra.

One of the most important features in *Pentremiteida* is given by the oral plates, which, in consequence of their very small size and close connexion with the summit, afford one of the most stable characters of the genus. In most of the species they are quite inconspicuous, and cannot be distinguished except as forming the dividing septum of the spir-

cles. They are visible in *P. lusitanica*, and again in *P. Schultzii*, but are of a much more elongated form in the latter species.

The species we propose to place in *Pentremitidea* are the following :—

Pentremites Pailletti, d'Orb. Devonian ; Asturias.

P. Schultzii, d'Orb. Ditto.

P. acutangulus, Schultze. Devonian ; Eifel.

P. clavatus, Schultze. Ditto.

P. eifelensis, F. Römer. Ditto.

Pentremitidea lusitanica, nobis. Devonian ; Spain
(? Asturias).

P. angulata, nobis. Ditto.

P. similis, nobis. Devonian ; Eifel.

Pentremitidea appears to be essentially a Devonian genus, being altogether unrepresented in the Carboniferous rocks. Half its known species occur in the Eifel, and the rest in the Asturias. The fine collection of Mr. Wachsmuth contains an unnamed Blastoid from the Upper Silurian or Lower Devonian of Charleston, Indiana, which we cannot distinguish from the Spanish *Pentremitidea Pailletti*. So far as we know at present, this is the only species of Blastoid which is common to Europe and America. We think it very probable that some of the more obscure American species of *Pentremites* will also have to be referred to this genus.

Pentremitidea lusitanica, sp. nov.

Sp. char. Calyx clavate-pyriform, elongated, expanding gradually upwards ; peristome truncate ; base elongate and pointed. Basal plates only a trifle shorter than the radials, forming an elongated cup, the lower portion of each plate bearing a strong central ridge, which assists in the ornamentation. Radial plates rather narrow, elongated, and arched from the lip downwards along the body. Three impressed lines diverge from the lip, one to each infero-lateral angle and one along the middle line. Radial sinuses with sharp erect margins, making an angle of about 134° with the truncated peristome ; lips a little thickened and simply rounded. Ambulacra elongately petaloid ; lancet-plates broad, almost wholly filling up the radial sinuses ; side plates large and oblong, their outer margins rounded, about fifteen in number on each side the ambulacra ; outer side plates narrow, bent down at a much greater angle than the side plates. Surface ornamented by fine close concentric raised lines parallel to the

margins of the various plates, those on the lower portions of the basal plates being of a peculiar V-shaped pattern.

Obs. This is a well-marked species, which may be at once distinguished from *Pentremiteida clavata*, Schultze, *P. acutangula*, Schultze, *P. Schultzii*, de Verneuil, and the two species next to be described, by the outline of the calyx. It differs sharply from *P. Pailletti*, the type of the genus, in the lobation of the radials, the smaller angle of inclination of the radial sinuses, and in their shorter length. *P. lusitanica* to a certain extent resembles *P. eifelensis*, F. Römer, of which Schultze has given a figure. Indeed, this species is its closest ally; but here, again, the radial angle is quite different, and gives to the Eifel species the appearance of possessing a longer and more curved sinus in each radial, and a very much less breadth across the peristome.

Loc. and Horizon. Asturias, Spain; Devonian (Mus. Nat. History).

Pentremiteida angulata, sp. nov.

Sp. char. Calyx pentagonal obpyriform, enlarging upwards to the distal extremities of the ambulacra, which are nearly equatorial; section decagonal, without re-entering angles between the ambulacra; summit small. Basal plates a little less than half the length of the radials, forming a strongly triangular cup, with three prominent angles, one corresponding to an interradius, the two others opposite ambulacra; surface of the plates between the angles hollowed out; base of attachment for the column triangular. Radial plates elongated, their surfaces in two planes which cut one another at the equatorial line of the calyx: the upper, sloping away to the summit, consists of the limbs; the lower, or the body below the radial lips, extends to the basiradial sutures and is hollowed out; a median ridge passes downwards from each lip to the basiradial suture, whilst the angle produced by the union of the two planes forms the greatest periphery or equator of the calyx. The lateral margins of the radial limbs are not placed in depressions, but the line of union of every two adjacent limbs forms a prominent angle of the calyx. Radial sinuses very narrow and long, with prominent lips. Oral plates quite apical. Ambulacra long and very narrow, maintaining almost the same width throughout their whole course; lancet-plates nearly as wide as the sinuses; side plates about twenty in number on each side of an ambulacrum, short but broad. Spiracles close round the mouth; anal spiracle with a prominent outer margin. Surface ornamented in the usual way.

Obs. This is a very interesting and peculiar species, representing, with that next to be described, one extreme type of the genus. The form of the calyx and the angulation of the radial plates will readily separate *P. angulata* from all the described species. The abruptly clavate outline indicates an approach to *P. clavata*, Schultze; but no other resemblance is observable; whilst with *P. similis* (nobis), although after the same general type, no definite comparison can be made.

There is a curious resemblance in external form between *Pentremitidea angulata* and *Phaenochisma caryophyllatum*, de Koninck sp., a member of a distinct genus that differs altogether from *Pentremitidea* in its other characters. *Pentremitidea angulata* is the aberrant species of the one genus as *Phaenochisma caryophyllatum* is of the other. Both agree to a certain extent in outward form, and differ in this particular from the other species of their respective genera.

Loc. and Horizon. Asturias, Spain; Devonian (Mus. Nat. History).

Pentremitidea similis, sp. nov.

Sp. char. Calyx pentagonal obpyriform, expanding rapidly upwards above the basiradial sutures; section strongly pentagonal, the greatest periphery being nearer the summit than the base; the latter is sharp, and the former depressed. Basals forming a small slightly expanded cup. Radials arched, broad at their bases, expanding very slightly upwards to the level of the lips, the limbs then rapidly decreasing to the summit, and forming strong projecting lobes around the calyx; sinuses very narrow, straight, the angle about 134° . Orals almost invisible. Ambulacra narrow.

Obs. Although we are only able to give a limited definition of this species, it is nevertheless sufficient to show how clearly distinct it is from any other *Pentremitidea*. On the other hand the resemblance of the calyx in general form to that of an *Orophocrinus*, especially that of the typical species *O. stelliformis*, is very remarkable; but here, of course, the resemblance ceases. The radial angle, the length of the ambulacra, and the greater amount of calycular surface between their distal extremities and the base of the calyx in *P. similis* separate it from *P. clavata*, Schultze, to which it is nearly related. The form of the radial plates in *P. angulata*, irrespective of other characters, at once separates the latter from *P. similis*. The Messrs. Sandberger have described a peculiar form from the Rhenish Devonian rocks, which is much too depressed a species to be confounded with ours, even supposing the former to be a *Pentremitidea*.

Loc. and Horizon. Eifel; Devonian (Mus. Nat. History).

Genus *PHENOSCHISMA*, gen. nov.

Gen. char. Calyx elongately clavate or obclavate; the number and disposition of the plates and general composition of the ambulacra similar to those of *Pentremites*. The oral plates are very small, inconspicuous, and always confined to the summit, where they are either horizontally placed or inclined inwards. The radials bear three more or less distinct folds diverging from the lips; and the two contiguous limbs forming the anal side are more or less abortive. Radial sinuses wide and deep, generally with steep sides. Spiracles as distinct apertures absent, the hydrospires opening externally by a series of elongated slits with intervening ridges, distributed in subparallel series on the sloping sides of all the radial sinuses; they are either both radial and oral or only radial in composition; and being only partially covered by the ambulacral plates, their distal ends (or even the entire length of some) are visible on the sides of the radial sinuses. Lancet-plate concealed by the side plates (in all but one species); outer side plates very small. Anus a separate opening, and further removed from the summit-centre than in *Pentremites*. Column, when compared with the size of the calyx, larger than in the last-named genus.

Obs. We have established *Phenoschisma* for a small number of interesting species hitherto included in *Pentremites*. The late Mr. E. Billings, in a remarkable article "On the Structure of the Crinoidea, Cystoidea, and Blastoidea"*, referred as follows to the peculiar structure of the ambulacra in *Pentremites caryophyllatus*, de Koninck †:—"The ends of the fissures of the hydrospires are seen along the sides of the angular ridges, which extend from the apices of the pyramids ‡ to the angles between the arms. I do not think that such species can be referred to *Pentremites*; and if I had specimens before me instead of figures only, I would most probably institute a new genus for their reception."

It affords us much pleasure to adopt the suggestion of Mr. Billings by proposing the name *Phenoschisma* for Blastoids possessing these characters. They differ from *Pentremites* in four essential points of structure—the absence of true spiracles around the peristome, the presence of a distinct anal

* Amer. Journ. Sc. 1869, xlviii. p. 80.

† Billings seems to have merely copied De Koninck's figure of this species (*l. c.* p. 79, fig. 11), which is erroneous in that the direction of these fissures is given from below the ambulacra outwards, whereas in reality they are subparallel to the latter (see 'Crinoïdes du Terr. Carb. Belgique,' 1854, t. 7. f. 3, b).

‡ *I. e.* the oral plates (= deltoids of authors).

orifice, the oral plates being of inconspicuous size and confined to the summit, and the marked change in the disposition of the hydrospires and their method of opening externally.

In *Pentremites* it will be remembered the hydrospires are situated internally immediately right and left of each ambulacrum, then communicate above with the common hydrospire-canal, which opens externally by means of the pores ranged along each side of the ambulacra, and also through the spiracles at the apex. But no part of the hydrospiral apparatus is visible externally, the whole of it being concealed by the lancet-plate and side plates of the wide ambulacra.

In *Phenoschisma*, on the other hand, the radial sinuses are much wider and deeper than are those of *Pentremites*. The lancet-, side, and outer side plates fail to fill them completely, and are confined, generally speaking, to the bottom of the cavity of each sinus. The spaces so left uncovered, consisting of the sides of the sinuses, formed by the inturned edges of the radials and orals, but chiefly, and sometimes wholly, of the former, are occupied by a variable number of subparallel slits, which are in fact the openings of the hydrospires exposed to view. The slits near the bottom of the cavities are the longest and most completely covered, and those near the top of each sinus the shortest, the outer ones being sometimes visible throughout their entire length. The number of the slits exposed and the amount of their exposure entirely depend on the relative size of the side and outer side plates, and how far they extend in a lateral direction towards the sides of the sinuses. In this way the hydrospiral canal and true spiracles are dispensed with, the hydrospires communicating directly with the exterior without the aid of any intermediate orifices.

Phenoschisma is allied to the genus *Codaster*, M'Coy, both in the structure of its respiratory organs and also in the absence of ambulacral pores. It differs, however, from M'Coy's genus in the partial exposure only of the hydrospiral slits, and in their presence in the anal interradius, as well as in the four others. *Phenoschisma*, in consequence, possesses ten groups of hydrospires, whilst *Codaster* has only eight. Further, the former genus has relatively smaller orals than the latter, and it may possess outer side plates to the ambulacra.

Phenoschisma differs from *Orophocrinus* in the fact that the ambulacra are nowhere in contact with the sides of the radial sinuses, as in Von Seebach's genus, and that the oral plates never show in a side view of the calyx. To *Pentremitidea* *Phenoschisma* stands in the same relation that it does to

Pentremites, except as regards the oral plates, which resemble those of the former genus.

Spiracles, in the true sense of the word, do not exist in *Phanoschisma*. At the same time there are visible in *Ph. acutum*, Phill. sp., some small openings at the central ends of the ambulaera, which may serve as such, and coexist with the exposed hydrospire-slits. They are imperceptible in *Ph. Archiaci*, nobis, but are present to some extent in *Ph. caryophyllatum*, de Kon. sp.

The species vary considerably in the amount of exposure of the hydrospirial slits. In *Ph. acutum* one slit is usually visible for the greater part of its length, though it may sometimes be entirely concealed upon one side of an ambulaerum. *Ph. caryophyllatum* shows one uncovered slit and the distal ends of four or five others, while in *Ph. Archiaci* two slits are completely visible and four others partially so.

Finally, the exposure is carried to the greatest extent in *Ph. Verneuli*, nobis, which has the majority of its slits uncovered.

So far as the genus is at present known to us, the form, with one exception, is elongately pyriform. The abnormal species is *Ph. caryophyllatum*, which is a shorter, rounder, and more depressed species than any of the others. Similarly the ambulaera are narrow in all but this species, where they become to a certain extent petaloid. Again, the side plates, except in the same species, lie actually on the lancet-plate, and not against it as in *Pentremites*. This is a feature which is very characteristic of the genus *Granatocrinus*, and is again seen in *Pentremitidea*.

The retention of the small and inconspicuous orals at the summit of the calyx, so that they are invisible in a side view, is a very marked feature in *Phanoschisma*, and a constant character throughout the genus. They are of larger size in the aberrant *Ph. caryophyllatum* than in any of the other species. We have succeeded in exposing the waternvascular ring of this genus, and find that it is of essentially the same character as that of *Pentremites*, *Orophocrinus*, and *Granatocrinus*. It is perhaps a little smaller, and the canals leading from the apertures in the lancet-plate rather longer.

The anal aperture varies in its character according to the species. For instance, in *Ph. Archiaci* the contiguous limbs of adjacent radials forming the anal interradius are shortened and truncated, so as partially to surround the anus. In *Ph. acutum*, Phill. sp., on the other hand, the cristiform aspect of the other interradii is in no way altered in the anal interradius, and the surface of the oro-anal plate is hollowed out for the partial reception of the aperture.

We propose to include the following species in the genus *Phanoschisma*:—

Pentremites acutus, Phillips. Carboniferous Limestone, England.

Pentremites caryophyllatus, de Koninck. Carboniferous Limestone, Belgium.

Phanoschisma Verneuli, nobis. Devonian, Spain.

Phanoschisma Archiaci, nobis. Devonian, Spain.

Our researches have not disclosed the existence of the genus during Silurian times; but it appears to have made its first appearance during the Devonian period, as represented by the Devonian rocks of Asturias, Spain. *Phanoschisma* reappears in the Carboniferous Limestone of England and Belgium, but, so far as we can ascertain, is unrepresented in the American Palæozoic rocks, unless *Pentremites kentuckiensis*, Shumard*, from the Subcarboniferous rocks near Louisville, Kentucky, be referable to this interesting type.

Phanoschisma Verneuli, sp. nov.

Sp. char. Calyx elongately pyramidal, with a sharp-pointed base and a hollow summit excavated in the direction of the rays. The ambulacra are separated by strong inter-radial processes, each of which is formed by the union of the adjacent limbs of two contiguous radials. Section distinctly pentagonal at the distal ends of the ambulacra. Basal plates forming an elongated cup about two thirds the length of the radials and a little longer than the bodies of those plates. Radial plates large, arched, with prominent lips, from which three folds diverge downwards; limbs long and projecting above the summit, except the two contiguous ones forming the anal interradius, which are flattened or depressed; sinuses very wide and deep, with high sloping sides. The four similar oral plates very small, but the anal-oral larger and diamond-shaped. Ambulacra linear, scarcely increasing in width; lancet-plate narrow, entirely concealed; outer side-plates very small and triangular; side plates from twenty to twenty-five, apparently oblong; hydrosfire-slits from twelve to eighteen, crowded together. Mouth small; anus roundly triangular. Surface ornamented by sharp striæ parallel to the margins of the plates. A distinct border follows the margin of each radial plate, defined by a faint groove.

Obs. *Phanoschisma Verneuli* needs no comparison with other species of the genus, except with *Ph. acutum*, Phill. sp.,

* Trans. St. Louis Acad. i. p. 239, t. ix. f. 13.

from which it differs in size, in the elevated nature of its interradii, and in its greater number of hydrospirial slits. As regards form, *Ph. Verneuli* represents one extreme modification of the genus, and *Ph. caryophyllatum* another.

Loc. and Horizon. Asturias, Spain; Devonian (Mus. Nat. History).

Phenoschisma Archiaci, sp. nov.

Sp. char. Calyx clavate, becoming more pentalobate with age. The angles of the pentagon correspond to the distal ends of the ambulacra; and its sides are concave, not straight. Base long and sharp; oro-anal surface truncate. Basal plates very long and slender, longer than the radials, expanding very gradually into a small cup, the surfaces ornamented with concentric striæ having two different directions. Radial plates small, lobate about the lips, projecting somewhat upward, and obliquely truncate on their upper margins; those of the anal interradius are a little flattened. Surface somewhat angular in the middle line from the lips down to the basiradial suture. Sinuses short, having a radial angle of about 130° , and somewhat petaloid. Orals confined to the immediate neighbourhood of the mouth. Ambulacra short, a little petaloid; lancet-plate lanceolate, narrow, deeply triangular in section; side plates few, six to eight or nine, oblong; outer side plates triangular, very small. Hydrospire-slits six on each side, the sixth partially covered by the lancet-plate, two only being entirely exposed when the side plates are in position. Hydrospires in the form of long, pendent, slender sacs. Mouth small; anus roundly triangular. Surface of plates ornamented with concentric striæ.

Obs. *Ph. Archiaci* does not possess the elevated interradial spaces of *Ph. Verneuli*, and is thereby distinguished from it, apart from their differences in other characters. The outline of the calyx generally, the form of the anal interradius, and the general features of the ambulacra and hydrospire-slits separate it from *Ph. acutum*. It is also unlike *Ph. caryophyllatum*, but may be said to be a transitional form between the two former species and the latter. The ornamentation of the basal plates is quite similar to that of a species of *Pentremitidea* (*P. lusitanica*), and might lead to a confusion of the two species should the generic characters not be properly attended to.

Genus CODASTER, M'Coy, 1849.

Codaster, M'Coy, Ann. & Mag. Nat. Hist. 1849, iii. p. 250.

Codaster vel *Codonaster*, M'Coy, Brit. Pal. Foss. 1851, fasc. i. p. 122, t. 3 D (expl.).

Codonaster, F. Römer, Wiegmann's Archiv für Naturgeschichte, 1851, xvii. Bd. i. p. 381.

Obs. Without absolutely redefining *Codaster*, we may say that, on the whole, we accept M'Coy's definition as accurately describing the characters of the genus. Some few emendations and additions are necessary. For instance, the radial plates (M'Coy's suprabasals) not only "reach to the truncated summit," but they are more or less inturned at the edge of the summit towards the apex, so as to form limbs in the usual way, which enclose narrow radial sinuses like those of other Blastoids. Oral plates also are present, appearing as diamond-shaped plates on the truncated summit in well-preserved specimens. Four of these bear along their median line the "thick, rapidly tapering ridges" of M'Coy, which are in no way an abnormal structure, but only represent the crests of the orals (and sometimes the combined orals and radials) of other genera.

So far as our own researches have gone, we have been quite unable to detect the supplemental basals described by Mr. S. S. Lyon* in any species examined by us. The "rough parallel striæ" and the "impressed lines" between them of M'Coy appear to have been a great stumbling-block to the earlier investigators of this genus. Lyon remarks, "the depressed triangular intervening spaces are filled with seven or more thin pieces lying parallel to the pseudambulacral fields, articulating with the summit of the second radials, and the prominent ridge lying between the pseudambulacræ. These pieces were evidently capable of being compressed or depressed"†. It is almost needless to observe that the view ascribing to the hydrospiral grooves the nature of distinct pieces is no longer tenable.

In 1861 Prof. James Hall observed that the striated inter-radial spaces of his *Codaster Whitei* "appear to be composed of separate linear plates like the pectinated rhombs of the Cystideans; and in one place, where broken through, they are seen to be discontinued almost to the inner face of the substance, giving the appearance of numerous thin parallel lamellæ"‡. These remarks may be said to have foreshadowed the important discoveries which were afterwards made by the late Mr. Rofe, and published in 1865. He found, by cutting

* D. D. Owen's 3rd Kentucky Report, p. 493.

† *Loc. cit.* p. 494.

‡ Boston Journ. Nat. History, 1861, vii. no. 2, p. 327.

thin sections for the microscope, "that the ridges on the striated interradiial surfaces are the tops of a series of folds of a thin test or membrane, the alternate folds being so united at the ends as to form a series of long but very narrow sacs;" and he further suggested their respiratory character*. These organs were called hydrospires by Billings†, who has confirmed Rofe's observations; and after a careful examination of Rofe's material, we are glad to be able to add our own testimony as to the accuracy of his descriptions. The full complement of hydrospires is deficient, as Mr. Billings has very justly pointed out, by two sets, in consequence of one interradius being completely occupied by the large vent‡; there are therefore eight sets, instead of ten as in the closely-allied *Phanoschisma*, *Pentremites*, and other genera. Owing to the direct communication of the hydrospire-slits with the exterior, there are no hydrospire-canal or spiracles.

From an examination of the British *Codasters* we can confirm the description given by Billings of the structure of the ambulacra in a Canadian species §. As there are no hydrospire-canal, there are no pores; and we doubt whether outer side plates are present in all species. Although we agree with most of Billings's descriptions of structural characters, we cannot accept his deductions from them as to the Cystid affinities of *Codaster*, a point which we shall touch upon later.

Messrs. Meek and Worthen have suggested|| that the puncta in the hydrospirial grooves communicate directly with the hydrospires, and represent the spiracles of other Blastoids. We cannot assent to this; nor are we at all clear that puncta exist in the impressed lines on the interradiial areas of *Codaster*. M'Coy only described them with doubt; and no definite evidence has presented itself amongst the large number of British specimens of *Codaster* examined by us. Neither do we see the slightest reason to suppose that any portion of the hydrospire-apparatus was capable of movement, as suggested by the following remark of S. S. Lyon¶:—"these pieces were evidently capable of being compressed and depressed."

The number of hydrospires varies considerably according to species. In M'Coy's *C. trilobatus* there are as many as

* Geol. Mag. 1865, ii. p. 251.

† Amer. Journ. Sc. 1869, xlviii. pp. 78-80.

‡ *Loc. cit.* 1870, xlix. p. 54.

§ *Loc. cit.* 1869, xlviii. p. 79.

|| Proc. Acad. Nat. Sci. Philad. 1869, p. 84 (note).

¶ D. D. Owen's 3rd Report Geol. Survey of Kentucky, 1857, p. 494.

ten exposed in each area, or sometimes nine exposed and one partly concealed under the side of the adjacent ambulacrum. In other varieties of this species we meet with seven grooves or slits; and some may be seen with eight. In *C. acutus*, M'Coy, the number varies from three in the young condition to four, five, or six, according to the state of growth; but invariably one and sometimes one and a half are concealed, as in *C. trilobatus**. The hydrospire-slits in *C. pyramidatus*, Shumard, are six or seven in number, and seven or more in *C. alternatus*, Lyon. Lastly, in *C. Hindei*, nobis, there are seven apertures on each of the interradial spaces, one of which is more or less covered by the edge of the ambulacrum.

We see no reason to doubt that *Codaster* possessed the usual plated integument over the central aperture, as noticed by Mr. Billings †; but we have not been fortunate enough to discover it in any of our British specimens. The outline of the ambulacra varies but little. They are lanceolate in the British species, narrow and linear in *C. americanus*, narrow in *C. Whitei*, and petaloid in *C. pyramidatus*. The side plates do not cover the lancet-plate entirely, but rest on its sides, leaving about a third of its width uncovered. The sides of the lancet-plate are always deeply notched for the reception of the side-plates. The latter vary in number according to species; the British form possesses from six to ten on each side. *C. Whitei* has twenty-three or twenty-four ‡, whilst in *C. pyramidatus* there are twenty-two. We have not been able to detect outer side plates in the British species; and, as before mentioned, there are no pores; but each side plate carries a large socket for the reception of the appendages. The structure of the ambulacra in the American *Codasters* appears to be somewhat different. Lyon described the ambulacra of *C. alternatus* as "divided into four equal parts by three indented lines." Shumard described and figured the same thing in *C. pyramidatus*; and the structure of our *C. Hindei* is identical. The middle one of the three indented lines is the ambulacral groove, the two lateral ones bounding the side plates, which here lie on and almost entirely conceal the lancet-plate. The outer side plates are placed outside the lateral "indented lines," and project somewhat upwards; pores were not observed.

The interradial or oral ridges present some marked pecu-

* These two so-called species appear to graduate into one another; and some doubt if they can be regarded as distinct.

† *Loc. cit.* 1870, xlix. p. 54.

‡ Boston Journ. Nat. Hist. 1861, vii. no. 2, p. 327.

liarities; and the outline of the summit depends very considerably upon the flatness or arched character of the plates which bear these ridges. In *C. pyramidatus* they are flat, broad, and lanceolate, sharp in *C. Whitei*, and barely separating the slits of adjacent interradii at their outer extremities. But they become wider towards the mouth; and their proximal ends in this species and in *C. alternatus* bear small tubercles. In the latter species the oral ridges project somewhat above the general surface of the summit and slope inwards; but in *C. pyramidatus* they are inclined outwards, and to a certain extent also in *C. Hindei*.

The radial sinuses are short in all the species, and usually triangular. The anus is either rhombic, as in *C. pyramidatus* and *C. trilobatus*, or ovate (*C. alternatus*). The column appears to have been circular and very small.

Codaster differs from *Pentremites* and *Granatocrinus* in the greater distinctness of the summit from the remainder of the calyx, in the absence of spiracles and the presence of the large interradiial anal opening, in the reduction in the number of the groups of hydrospires from ten to eight, owing to their absence from the anal interradius, in this opening directly to the exterior instead of being withdrawn beneath the ambulacra, and, lastly, in the absence of hydrospire-pores. The same characters also separate *Codaster* from *Pentremitidea*, *Schizoblastus*, *Tricelocrinus*, and *Troostocrinus*. There is a nearer affinity existing between *Codaster* and *Phaenoschisma* in the exposure of the hydrospiral slits on the surface of the calyx, and in the absence of definite spiracles; but in the latter genus the anal interradius is occupied by hydrospires, and the outline of the calyx in the two genera is quite different.

Codaster was established by M'Coy as a Blastoid; but Mr. Rofe* regarded it as a connecting-link between the Crinoidea and Cystoidea, *Pentremites* being more closely allied to the former, and *Codaster* to the latter. On the other hand, Billings† definitely referred it to the Cystoidea, because there is no connexion between its hydrospires and the cavities of the pinnulæ borne on the ambulacra, such as he assumed to exist in *Pentremites*.

We cannot learn that any other palaeontologist but Prof. Zittel‡ has definitely adopted this view, which is far from commending itself to us. If *Codaster* is a Cystoid, so are

* Geol. Mag. 1865, ii. p. 251.

† Amer. Journ. Sc. 1869, xlviii. p. 80.

‡ Handb. d. Pal. 1880, Bd. i. Abth. 1, p. 424.

Orophocrinus and *Phenoschisma*, which are also devoid of pores at the sides of the ambulacra leading into the hydrospires. But *Codaster* is a true Blastoid in every respect; and we think that Billings was led to this erroneous conception by his not having emancipated himself from the old doctrine of the pinnules of *Pentremites* being placed directly over the hydrospire-pores bordering the ambulacra, a theory now abandoned by all the more prominent writers on the Blastoidea.

The following species are comprised in the genus *Codaster* :—

- * *Codaster acutus*, M'Coy. Carboniferous Limestone, England.
- C. alternatus*, Lyon. Upper Helderberg group (Lower Devonian), Kentucky.
- C. americanus*, Shumard. Upper Helderberg group (Lower Devonian), Kentucky.
- C. pyramidatus*, Shumard. Upper Helderberg group (Lower Devonian), Kentucky.
- * *C. trilobatus*, M'Coy. Carboniferous Limestone, England.
- C. Whitei*, Hall. Burlington group (Subcarboniferous).

Codaster thus appeared first in the Lower Devonian of North America, and was represented by three species. It extended into the Carboniferous Limestone of the same continent and of the British Islands; but we believe it to be unknown in the Upper Palæozoic rocks of the continent of Europe.

If the Blastoid described by Messrs. Miller and Dyer as *Codaster pulchellus* † belongs to this genus, which we very much doubt, *Codaster* will then range back in time as far as the Niagara group (Wenlock).

Codaster Hindei, sp. nov.

Sp. char. Calyx obtusely conoid and wall-sided; summit more or less truncated and decagonal; oral crests of nearly equal length with the ambulacra. Basal and radial plates about equal in length, the latter convex, most sharply so in the middle line; but the limbs are placed at such an angle that the union of every two produces a perfectly flat side to the calyx; sutures not marked by any depression; sinus rhombic. Four regular oral plates rhomboid and arched, with a narrow sharp oral ridge, either in the same general plane with the summit or inclined very slightly outwards,

* Probably identical.

† Journ. Cincinnati Soc. Nat. Hist. 1878, t. ii. f. 13.

and terminating around the mouth in blunt processes. Ambulacra lanceolate-petaloid, tapering but little, with a well-marked food-groove, and another groove on each side sub-parallel to it. Lying on the lancet-plate between the food-groove and these lateral grooves are the side plates, that portion of the ambulacra outside the latter being in all probability firmly anchylosed outer side plates; pinnule-sockets large. Hydrosfire-slits seven in number in each interradius, half exposed, and one covered by the edge of the adjacent ambulacrum. Mouth very small; anus rhomboid. Surface smooth in the example under examination, but probably ornamented by striæ following the margins of the plates.

Obs. We are indebted for this interesting species to our friend Dr. G. J. Hinde, who believes it to be identical with *Codaster canadensis*, Billings (MS.). The few remarks* made by Mr. Billings about *C. canadensis* are quite insufficient for its identification; and we have therefore much pleasure in associating our specimen with the name of its discoverer, who has so earnestly worked in the field of Canadian palæontology.

The form of the radial plates, irrespective of other characters, at once distinguishes *C. Hindei* from *C. pyramidatus*, Shumard, and therefore probably also from *C. americanus* of the same author. The diagnosis of *C. Whitei*, Hall, partakes more of a generic than of a specific character; but it also appears to be a distinct species. The length of the radial sinuses and ambulacra, and the angle at which they are inclined to the general plane of the summit, sharply distinguish *C. alternatus*, Lyon, from *C. Hindei*, and give the two species a very different appearance. Further, in the summit of the former, when viewed from above, portions of the inturned upper edges of the radial plates are visible; but in *C. Hindei* the perpendicular position of the sides of these plates quite prevents their appearing on the ventral aspect, where nothing is visible but the true summit-characters.

Loc. and Horizon. Arkona, Ontario, Canada. Hamilton Group, Upper Devonian (Coll. G. J. Hinde, Ph.D., F.G.S.).

Genus GRANATOCRINUS (Troost, 1850, MS.), Meek & Worthen (redef. E. & C. 1882).

Orbitremites, J. E. Gray (MS.), Synop. Brit. Mus. 1840, p. 63.

Granatoerinites, Troost (MS.), Proc. Amer. Assoc. Adv. Science for 1849, p. 62.

* Amer. Journ. Sc. 1869, xlviii. p. 79.

Granatocrinus, (pars) Hall, 15th Annual Rep. State Cab. N. York, 1862, p. 146; (pars) Shumard, Trans. St. Louis Acad. 1865 (?), ii. p. 375; (pars) Meek & Worthen, Illinois Geol. Survey Report, 1866, ii. p. 274.

Obs. The majority of American palæontologists have agreed to distinguish as a separate genus a series of forms having the general structure of *Pentremites Norwoodi*, O. & S., *P. melo*, O. & S., and *P. Sayi*, Shumard. To these have been applied the name *Granatocrinus*, which was first proposed by the late Dr. G. Troost as *Granatocrinites*, the type being the *G. cidariformis*, Troost. Neither of these ever became more than a MS. name; and, according to Dr. Shumard*, the species is identical with *Pentremites granulatus*, Römer. The latter unfortunately is equally little known, having been described only from an internal cast, no mention being made of the summit-characters. Under these circumstances, and for a due appreciation of the generic characters, we are obliged to seek another type. We believe this may be most readily found in *Pentremites Norwoodi*, O. & S., not only from its general acceptance as a typical *Granatocrinus*, but as one of the species first referred to this genus.

We believe that Prof. James Hall was the first to use the name *Granatocrinus* †, although without any precise definition, and after him Dr. Shumard ‡, who included in it a larger number of species than have been retained by later American writers. The first actual description of *Granatocrinus* to appear was by Meek & Worthen§, who supplement their definition by the following remarks:—"The generic formula of this group is exactly the same as that of *Pentremites*, Say, so far as regards the number and arrangement of the pieces forming the body, though the form and proportions of these pieces are so unlike as to give a very different outline and general physiognomy to the entire fossil. They are therefore readily distinguished from Say's genus, as properly restricted, by the irregular oval, elliptical, or subglobose form, concave or less protuberant base, and much narrower and more elongated pseudo-ambulacral areas, which extend the entire length of the body, so as to give it more the appearance of an Echinoid. They likewise present differences in the arrangement of the ovarian(?) openings of the summit, which are more intimately connected with the interradial pieces, being sometimes excavated one into each lateral

* Trans. St. Louis Acad. ii. p. 375.

† 15th Annual Report State Cab. Nat. Hist. New York, 1862, p. 146.

‡ *Op. cit.*

§ Illinois Geol. Survey Report, 1866, ii. p. 274.

margin of these pieces (*G. Sayi*)—or, in other instances, piercing directly through them, so that each pair appears externally as a single opening (*G. melo* and *G. Norwoodi*), though they divide into two distinct canals before passing entirely through the plates. The typical forms of this genus also have the interradiial pieces proportionately much larger than in the true *Pentremites*, though this is not a constant character.”

On a comparison of the species thus separated from *Pentremites* and united under *Granatocrinus*, we find that they belong to two well-defined morphological groups. To the first of these, having for its type *Pentremites Norwoodi*, O. & S., we propose to restrict the name *Granatocrinus*; and to the other, typified by *Pentremites Sayi*, Shum., we apply the name *Schizoblastus*.

The lancet-plate of an ordinary *Pentremites* does not fill the radial sinus, but only occupies its central portion. Between it and the walls of the sinus therefore a groove is left, at the bottom of which are the slits of the hydrospires. This groove is continued from the peristome on either side of the apical end of each oral piece and down to the end of each ambulacrum. It is not, however, left open, but is converted into the “hydrospire-canal” by the side plates, which are wedged in between the lancet-plate and the walls of the sinus. In the proximal portions of the ambulacra these walls are formed by the oral plates, the central ridge of which is sometimes comparatively prominent, so as to separate the proximal side plates of adjacent ambulacra, but sometimes so reduced that these plates meet their fellows over the top of the oral ridge. In either case, however, the passage from the peristome between the lancet-plate and the calycular plates becomes converted into a canal, which is roofed over by the side plates and opens at the summit by the so-called spiracle. This is the structure of the summit in *Pentremites* proper.

In *Granatocrinus Norwoodi*, and in all the species met with in British rocks, with one exception, the lancet-plate almost entirely fills up the radial sinus, and the narrow hydrospirial canals are continued upwards *through the substance of the oral plates**, opening externally usually by five, but in one case (*G. Rafii*) by ten, apertures †. Most of the other

* This structure was originally described by Dr. C. A. White in *G. Norwoodi* (Boston Journ. Nat. Hist. 1863, vii. no. 4, p. 483).

† We have a specimen of *G. Norwoodi* in which one of the oral plates is pierced by *two* spiracular openings instead of by one only. This is the natural condition of four of the oral plates of the British *G. Rafii*, the fifth one having a large anal spiracle as in all the species of this genus.

American species referred to *Granatocrinus*, as *G. melo* and *G. Sayi*, have ten *notches* in the sides of the oral plates, instead of pores, and will constitute our genus *Schizoblastus*.

The species forming *Granatocrinus* so emended are the following:—

I. Typical Species.

<i>G. Norwoodi</i> , O. & S.	Burlington Limestone (Sub-carboniferous), Iowa.
<i>G. ellipticus</i> , Phill.	Carboniferous Limestone, England.
<i>G. derbiensis</i> , Phill.	” ” ”
<i>G. orbicularis</i> , Phill.	” ” ”
<i>G. campanulatus</i> , M'Coy.	” ” ”
* <i>G. pisiformis</i> , sp. nov.	” ” ”
<i>G. M'Coyi</i> , sp. nov.	” ” ”

II. Aberrant and Doubtful Species.

G. elongatus, Phill.; *G. Rofsi*, sp. nov. Both from the Carboniferous Limestone.

The form and general appearance of the calyx presents a remarkable uniformity of type throughout the species which we have restricted under the name of *Granatocrinus*. Two broad divisions may be traced—the first after the type of *G. Norwoodi*, the second after that of *G. ellipticus*. In the first the form is subglobose; and, includes all the British species except the one named. The latter forms a division of itself and is elongately elliptical.

The summit is more or less flattened in all, or even at times a little depressed. The base is usually small, flattened, or concave, the amount of the concavity varying according to species, the basal plates never being visible in a side view: in *G. Norwoodi* it is narrow and deep, in *G. orbicularis* broad and shallow, the same in *G. ellipticus*, rather deeper in *G. derbiensis*, broad and almost flat in *G. campanulatus*, in fact broader in this species than in any other.

The proportions of the radial and oral plates of *Granatocrinus* vary considerably; some species have large radials and small orals, others small radials and large orals. Generic subdivision has before now been attempted according to the relative sizes of these plates; but, as Messrs. Meek and Worthen have very justly observed, speaking of the orals in particular, “there are so many gradations in this character, however, that it does not seem to be possible to make it a means of separating the species into two well-defined sec-

* These will be described in our more extended work on the Blastoidea.

tions"*. In this we entirely concur. *G. Norwoodi* possesses very large radial plates, extending from the edge of the hollow base almost to the very apex of the calyx, and correspondingly small orals. On the other hand, in the British species, although the radials maintain their general superiority of size in all but one species, the orals are larger than in the American type. A gradation, however, is traceable in *G. pisiformis*, in which they are smallest, to *G. orbicularis*, which possesses the largest oral plates with the exception of *G. derbiensis*. In the latter they attain an inordinately large size, the radial plates being only just sufficiently high to enclose within their sinuses the distal ends of the long ambulacra. The spiracles open in all the species, whether the oral plates are large or small, on the mamillary projections at the apices of the latter †; but in *G. pisiformis* they are bounded externally by nodular elevations of the plates. Dr. C. A. White has shown that the anal spiracle in *G. Norwoodi* is bordered on the outer side by a solid projection formed by a part of the oral plate ‡. Meek and Worthen suggested that the anal plate consisted of three pieces §; but we have not met with any evidence confirming this view.

The ambulacra of *Granatocrinus* are always long, curved, and narrow, and reaching to the base—the calyx usually resting, when placed on its base, on the distal ends of the ambulacra. This appears to be an essential character of the genus, and is one of the points in which it agrees with *Schizoblastus*. The side plates in the ambulacrum of *Granatocrinus*, unlike those of *Pentremites*, do not lie against the sides or edges of the lancet-plate, but actually upon it, so as to conceal the greater part of it. The portion left exposed is the crenulated ridge of the lancet-plate, bearing the zigzag ambulacral or food-groove. This is the structure in *G. ellipticus*, *G. campanulatus*, *G. orbicularis*, and *G. derbiensis*, whilst in *G. Norwoodi* it is perhaps more exposed than in any other species we have as yet been able to refer to this genus. The side plates are variable in number according to species (from twenty to eighty), and are usually transversely elongated. The ambulacra are at times deeply impressed within the prominent edges of the radial forks.

A good deal of variation is shown in the formation of the pores. In *G. orbicularis* they are enclosed between the margin

* Illinois Geol. Report, ii. p. 275.

† First pointed out in *G. Norwoodi* by Owen and Shumard (Journ. Acad. Nat. Sciences Philadelphia, 1850, ii. pt. 1, p. 64).

‡ Boston Journ. Nat. Hist. 1863, vii. no. 4, p. 483.

§ Illinois Geol. Surv. Rep. 1873, p. 465.

of the radial, the lower margin of the side plate above, and the upper oblique margin of the outer side plate, and are, roughly speaking, triangular in shape. The result of this is that the pores are excavated wholly in the outer side plates; but in *G. ellipticus* a slightly different arrangement is met with. Here the pores are excavated out of the side plates themselves, the upper edge of the outer side plates being quite straight and not at all cut into. In *G. campanulatus* the pores are scarcely excavated in the ambulacral plates at all, but are almost wholly so in the edges of the radial plates. There also appear to be slight modifications in the arrangement of the sockets placed on the side plates. In *G. orbicularis* they terminate narrow grooves which arise from the lower sutures between the side plates and the outer side plates, running almost straight on to the centre of each side plate. There is a similar structure in *G. elongatus*, a somewhat aberrant form, which will probably have to be referred to the present genus. But in *G. ellipticus* the groove communicating with the socket arises from the suture separating the side plates themselves, and must have been in direct communication with the pore.

We have come to the conclusion that in *Granatocrinus*, as understood by us, there is no under lancet-plate, as there is in *Pentremites* and *Orophocrinus*; and we are glad to find ourselves in accord with Messrs. Wachsmuth and Springer on this point*.

In *Granatocrinus* the hydrospires are few in number. *G. Norwoodi* possesses two on each side of an ambulacrum, whilst *G. campanulatus*, *G. orbicularis*, *G. ellipticus*, and *G. derbiensis* have only one each. The abnormal species *G. elongatus*, to which we shall refer further on, possesses three on each side.

The central aperture and spiracles in the type species *G. Norwoodi*, as originally pointed out by Messrs. Owen and Shumard, are closed by a conical integument of small plates †; but our researches amongst the British species have not rewarded us by the discovery of a similar feature. Through the disinterested kindness, however, of Mr. Charles Wachsmuth we have been afforded the opportunity of examining some fine examples of *G. Norwoodi* in that condition. It has also been pointed out by Dr. C. A. White that in the same species this plated integument passes down and covers the central food-groove of the ambulacra ‡.

* 'Revision,' pt. 2, t. xx. f. 6.

† Journ. Acad. Nat. Sciences Philadelphia, 1850, ii. pt. 1, p. 65; also see Shumard, in Swallow's Missouri Geol. Report, 1855, p. 186.

‡ Boston Journal, *l. c.* p. 484; see also Meek and Worthen, Proc. Acad. Nat. Sciences Philadelphia, 1869, p. 85.

The calyx in *Granatocrinus* is highly ornate. Concentric striae, often becoming reticulate, or fine granules arranged in lines, cover the plates.

We append a list of doubtful species of "*Pentremites*," which we have been unable to refer either to *Granatocrinus* or to *Schizoblastus*. We have not seen specimens of any but the first mentioned; and though figures have been published of some, they are of as little use as most of the specific diagnoses for the determination of the generic affinities of these doubtful forms:—

- Pentremites angularis*, Phillips. Carboniferous Limestone, England.
P. curtus, Shumard. Archimedes Limestone (Subcarboniferous), Missouri.
P. Shumardi, M. & W. Burlington group (Subcarboniferous, Iowa).
P. Roemeri, Shumard. Chemung group (Upper Devonian), Missouri.
 ?*P. calyce*, Hall. Hamilton group (Upper Devonian), W. New York.
 ?*P. leda*, Hall. Hamilton group (Upper Devonian), W. New York.
 ?*P. lycorias*, Hall. Hamilton group (Upper Devonian), W. New York.
 ?*P. maia*, Hall. Hamilton group (Upper Devonian); Moscow, New York.
P. cornutus, M. & W. St.-Louis group (Subcarboniferous), Illinois.
P. granulatus, Roemer.
P. loboblastus, White. Subcarboniferous, Arizona.

We possess in our English Carboniferous Limestone a species, *Pentremites elongatus*, Phillips, which is to all intents and purposes a *Granatocrinus*, so far as general appearance goes. The ambulacra, however, are relatively wider than in a typical *Granatocrinus*; and the spiracles are formed more after the type of *Pentremites* proper. The contracted apex and base, with concavity of the latter, the long curved ambulacra, long radials, and small orals, correspond nevertheless so closely with those of the former genus that we feel somewhat undecided at present whether to place it there or frame a separate genus for its reception.

In its emended form *Granatocrinus* is strictly confined to rocks of Carboniferous age—one species being found in the United States of North America, and six in England. On the

other hand, the number of American species may at any moment be augmented by one or more of the doubtful ones. Further, if certain forms described by Prof. James Hall are subsequently found to be referable to this type, the genus will have commenced its existence in the Upper Devonian of North America.

Genus SCHIZOBLASTUS, gen. nov.

Gen. char. Calyx resembling that of *Granatocrinus* in form and composition of the ambulacra. Oral plates of variable size, but usually small. Spiracles double, being linear or oval clefts between the lancet-plate and notched edges of the orals, further removed from the peristome than in *Pentremites*, and not floored by the oral plates (as in the latter genus); those in the anal interradius may or may not be confluent with the anal aperture.

Obs. That some restriction of the then existing genus *Granatocrinus* was felt to be necessary by American palæontologists may be gathered from the following remarks by Messrs. Meek and Worthen, who, speaking of *Pentremites melo* and *P. projectus*, say, "Both of these forms differ from the typical species of *Pentremites*, in having each pair of ovarian openings distinctly separate, instead of closely united, with merely a thin septum between . . . They constitute a subgenus of *Pentremites*"*. The form of the calyx in *Schizoblastus* is, as a rule, pentagonal subglobose, or melon-shaped, and when viewed in section is either simply pentagonal, as in *S. Sayi*, or imperfectly decagonal, as in *S. melo*, *S. melonoides*, or *S. missouriensis*. The summit and base are much contracted when compared with the apices of other genera. The former is, generally speaking, to some extent flattened, whilst the latter varies between very concave, truncate, or slightly protuberant. In *S. melo*, *S. Sayi*, *S. melonoides*, and *S. missouriensis* the concavity is but slight, in some individuals so much so as to appear almost flat, whilst in *S. glaber* it is broad and apparently truncate. On the other hand, in *S. granulatus* the base is deeply concave, the radial plates being quite hidden in the depression, so that they are invisible in a side view. A similar concavity also exists in *S. pisum*. Lastly, in *S. neglectus* and *S. projectus* the base projects to a greater or less degree, and is visible when the calyx is placed in an erect position before the observer.

The radial plates resemble those of *Granatocrinus* by their extreme variability in size. In *S. melo*, *S. melonoides*, and

* Proc. Acad. Nat. Sciences Philadelphia, 1861, p. 142.

S. projectus they are very large, extending through all but the whole length of the calyx. Those of *S. Sayi*, on the contrary, are exceedingly short, extending upwards only sufficiently far to enclose the distal ends of the long ambulacra in their forks or sinuses. In *S. glaber* and *S. missouriensis* the radials are again short, but not quite to the same extent as in *S. Sayi*, whilst in the former they are much incurved below, to assist in forming the truncate base. The radial sutures are placed in concavities or re-entering angles of the calyx in *S. melo*, and, to a certain extent, in *S. missouriensis*, giving to the entire body a markedly lobate appearance, and to the cross sections a roughly decagonal outline. The oral plates of this genus have no depressed apical tongues more or less divided by a median ridge into two lateral halves, each of which forms the floor of a spiracle, as is the case in *Pentremites*. The size of the orals is naturally in inverse proportion to that of the radial plates. For instance, they are very small in *S. melo*, *S. melonoides*, and *S. projectus*, and confined quite to the summit. They are comparatively small again in *S. pisum*, but of medium size in *S. glaber* and *S. granulatus*, and more than one third the length of the body in *S. neglectus*. In *S. Sayi*, on the contrary, the orals reach their extreme limit of size, to compensate for the diminished radial plates. This species occupies the same position in *Schizoblastus* that *G. derbiensis* does in *Granatocrinus*, the relation of the two sets of plates in question affording a very marked point of resemblance between the two genera.

The spiracles are oval or linear slits, one on either side of each ambulacrum, but situated at a relatively greater distance from the centre than those of *Pentremites*. The hydrospire-cleft between the edge of the lancet-plate and the side of the radial sinus is roofed over and converted into a canal by the side plates, the outer faces of which rest against the straight edges of the orals at the proximal ends of the ambulacra. These straight edges, however, are not continued right up to the peristome. Some little distance before reaching it they bend inwards towards one another, and then curve outwards again before converging towards one another at the apex of the plate. At these points, therefore, the hydrospire-clefts are slightly wider than at the more distal parts of the ambulacra; and as the latter decrease in width the side plates fail to fill up the gap between the lancet-plate and the orals, which is thus left open as a spiracle, and is not closed by the summit-plates when these are present. The spiracles of *Schizoblastus*, speaking generally, are much more outside the orals than those of *Pentremites*. It is well shown in *S. Sayi*,

where the anus perforates one of the oral plates, while the spiracles are partly formed by notches in its side*. The spiracles vary but little in size, and, as a rule, are very small, as in *S. pisum*, *S. neglectus*, *S. melo*, &c., but of larger size in *S. glaber*. The anal spiracle is always very disproportionate in size as compared with the others. It is frequently bounded on its outer margin by a tubercle or boss of greater or less elevation, as in *S. neglectus*, *S. granulatus*, and *S. melo*. The anal opening is said to be circular in *S. pisum*, ovate in *S. Sayi*, and pyriform in *S. melo*. The summit of *S. melo* presents some departures from the type described above, which approximate it to *Pentremites* proper. This is especially marked in specimens which have the side plates *in situ* at the central ends of the ambulacra. A wide median ridge rising from the apex of each oral plate separates two spiracular openings, which are apparently constructed upon the same type as those of *Pentremites*, viz. floored by oral plates and leading into a hydrospiracular canal, roofed in by side plates.

The real state of the case, however, is as follows:—The lancet-plate is separated from the radial plates by the thick upper edge of the inner wall of the hydrospire-tubes. Minute cross pieces between this plate and the sides of the radials convert the hydrospire-cleft into a canal opening externally by pores between these cross pieces, whilst the side plates, resting on the latter, alternate with the pores as usual. But this hydrospire-plate terminates at the oro-radial suture; and at the central end of the ambulacra the lancet-plate comes into direct and continuous contact with the orals without leaving any intervening pores, although the side plates rest on it as usual. Between the converging edges of the lancet-plate and the large notches in those of the oral plate at its sides are the spiracular openings, which lead downwards beneath the lancet-plate into the hydrospiracular canal, and are not floored by the oral plates, as are those of *Pentremites*. But the anal spiracle

* The peculiar manner in which the spiracles of *Schizoblastus* are formed is excellently shown in Wachsmuth and Sprünger's figure of *S. Sayi* (Revision, ii.). But we cannot at all acquiesce in their interpretation of the calycular plates of this type. It is generally supposed to have large orals which form the greater part of the calyx. The above-named authors, however, limit their name to small rhomboid pieces immediately round the summit, which we take to be merely the apical ends of large oral plates. Further, they represent a suture as occurring below these tongues and the great plates outside them, which they indicate as the fork-piece (radials). We cannot, however, make out either this suture or the interradial one represented by them as between the two limbs of adjacent radials; for the latter occupies the middle line of what we, like earlier writers, take to be large deltoid or oral plates.

is so large as to remove all trace of the broad median ridge separating the two spiracles at the sides of the corresponding oral plates; and the lateral tubes are therefore fused with the anus into one large anal spiracle—a character which increases the resemblance between the summit-structure of this species and that of *Pentremites* proper. Except in *S. melo*, the spiracles of *Schizoblastus* are at the sides of the proximal side plates, whilst those of *Pentremites* are between the latter and the mouth.

We have not succeeded in ascertaining whether or not the lancet-plate is double, as in *Pentremites*; but we believe that it is not. In *S. Sayi* it is undoubtedly traversed by three canals, one being that of the water-vessel. The nature of the other two is not at present clear to us; but we hope to discuss the question fully in our larger work. The side plates in *Schizoblastus* rest on the lancet-plate, partially hiding it from view, and not simply against it as in *Pentremites*.

It is scarcely visible in *S. melonoides*, *S. pisum*, and *S. neglectus*, rather more exposed in *S. melo*, and still more so in *S. Sayi*, in which it occupies the median third of the ambulacrum. The side plates vary from about twenty to eighty in number on each side of the ambulacrum. They number about twenty-six in *S. pisum*, from twenty-five to thirty in *S. neglectus*, *S. glaber*, and *S. granulatus*, and eighty in *S. Sayi*. Outer side plates are unknown in *S. melonoides*, *S. pisum*, *S. neglectus*, and *S. glaber*.

We are acquainted with the number of hydrospires in only *S. Sayi*, in which there are four on each side.

Not unfrequently a sulcus of variable depth occurs on each side the ambulacra, between the ends of the side plates and the edges of the radial sinuses. The ambulacra are either on the same level with the general surface of the calyx, as in *S. Sayi* and *S. projectus*, or a little below it, as in *S. granulatus*.

The surface of the plates in *Schizoblastus* is usually highly ornate; but *S. glaber* is described as smooth. The species definitely included in this genus are:—

Pentremites melo, Owen and Shumard. Subcarboniferous, Iowa, Missouri, Illinois, &c.

P. Sayi, Shumard. Ditto.

Granatocrinus melonoides, Meek & Worthen. Burlington group (Subcarboniferous), Iowa.

G. pisum, Meek & Worthen. Burlington group, Iowa.

G. neglectus, Meek & Worthen. Ditto.

G. glaber, Meek & Worthen. St.-Louis group, Illinois.

- Granatocrinus granulosus*, Meek & Worthen. Keokuk group (Subcarboniferous), Illinois.
Pentremites missouriensis, Shumard. Chemung (Devonian), Missouri.
Granatocrinus projectus, Meek & Worthen. Burlington group (Subcarboniferous), Iowa.
Pentremites Potteri, Hambach. Ditto.

With the exception of one species, *S. missouriensis*, which is found in the Chemung group (a division of the North-American Devonian), the whole of the species are of Carboniferous age, and confined to America.

Genus TROOSTOCRINUS, Shumard, 1865.

Troostocrinus, Shumard, Trans. St. Louis Acad. 1865, ii. p. 384 (note); Meek & Worthen, Illinois Geol. Report, 1873, v. p. 507.

Obs. This genus was proposed by Dr. Shumard, in his useful Catalogue of North-American Palæozoic fossils, for subfusiform species of *Pentremites*, after the type of *P. Reinwardtii*, Say, possessing a slender outline, triangular base, and linear ambulacra. The genus was never described in detail, but was adopted by Messrs. Meek and Worthen provisionally. To it they ascribe species with a triangular base, flattened on all three sides, a narrow fusiform body, elongate and tapering below, and narrow ambulacra.

Dr. Shumard's remarks are as follows:—"There appear to me good reasons for removing this and other subfusiform species, as *Pentremites Reinwardtii*, *P. lineatus*, *P. bipyramidalis*, *P. Wortheni*, and perhaps *P. Grosvenori*, from among the *Pentremites*, and grouping them together in a separate subsection under another name. These and allied forms are remarkable for their slender subfusiform shape, linear pseud-ambulacral fields, triangular base, and simple summit-structure. These external differences would seem to imply corresponding modifications in the internal economy of the animals of more than specific importance. If, from a more thorough study of such species, it should be deemed advisable to separate them from the genus *Pentremites*, I would propose the name *Troostocrinus* for the group," &c.*

In this proposal we entirely concur; but as our acquaintance with the genus depends simply on the structure of *T. Reinwardtii* and *T. lineatus*, we shall confine our descriptive remarks to these species. The most important morphological difference between *Troostocrinus* and *Pentremites* lies in the

* *L.c. cit.*

structure of the spiracles. Those of *Troostocrinus* are at the sides of the proximal side plates, as in *Schizoblastus*, while those of *Pentremites* are between the proximal side plates and the mouth. The spiracles, more especially those of *T. lineatus*, are intermediate in structure between those of *Pentremites* and the American species of *Orophocrinus*. The distal portions of the ambulacra resemble those of a *Granatocrinus*, the lancet-plate and its superposed side plates almost completely filling up the radial sinus, so that the hydrospiral pores are small and inconspicuous. Towards the summit, however, the width of the deep radial sinuses increases considerably, while that of the ambulacra decreases a little, and the side plates do not meet the orals. The hydrospiral canals therefore open out into linear spiracular apertures, those of the anal side being nearer the centre than, and quite distinct from, the anus. If the distal portion of the lancet-plate were in continuous instead of interrupted contact with the sides of its radial sinus, *T. lineatus* would have the same form of respiratory openings as *Orophocrinus gracilis*, M. & W. sp., a slit extending for a short distance along each side of the ambulacra.

On the other hand, if the summit were rounder, the radial sinus shallower, and the spiracles shorter and wider, *Troostocrinus* would be essentially a *Pentremite* with narrower ambulacra than usual. Therein lies the difference between the two types, and also between *Troostocrinus* and *Pentremiteida*. We believe that this form of spiracle, coupled with the characters indicated by Dr. Troost, will prove to be of generic value; and we propose to adopt *Troostocrinus* accordingly.

The peristome is more contracted in *T. Reinwardtii* and *T. lineatus* than in almost any other Blastoids. The oral plates are very minute, entirely confined to the summit, as well as inconspicuous, like those of *Pentremiteida* and *Phaenoscisma*. The ambulacra are deeply set in the radial sinuses, but deeper in *T. lineatus* than in the other species. The side plates are few in number in *T. Reinwardtii*, but much more numerous in *T. lineatus*. The lancet-plate is almost entirely concealed by the side plates, as in some species of *Granatocrinus* and *Schizoblastus*. In *T. lineatus* it contains three canals arranged in a triangle, similar to those of *Schizoblastus*. The hydrospires, in the only two forms in which we have seen them, are three or four in number on each side; *T. Reinwardtii* possesses three, and *T. lineatus* four.

The following is a full list of the species which will probably be comprised in *Troostocrinus* *:—

* We are acquainted by examination with the two type species only,

- Pentremites bipyramidalis*, Hall. Keokuk limestone (Subcarboniferous), Missouri.
P. clavatus, Hambach †. Subcarboniferous, Illinois.
P. Grosvenori, Shumard. Archimedes limestone (Subcarboniferous), Indiana.
P. lineatus, Shumard. Enderinital limestone (Subcarboniferous), Illinois.
P. Reinwardtii, Troost. L. Helderberg group (Upper Silurian), Kentucky.
P. subcylindrica, Hall. Niagara group (Upper Silurian), Ohio.
P. subtruncatus, Hall. Hamilton group (Up. Devonian), Iowa.
P. Wortheni, Hall. Keokuk limestone (Subcarboniferous), Iowa &c.

If all the above species are rightly placed under *Troostocrinus*, the genus then made its first appearance in the Upper Silurian, reappeared in the Upper Devonian, and culminated in the Carboniferous. We are not acquainted with any *Troostocrinus* from the Palaeozoic rocks of this country or of the continent; so that it appears to be entirely an American genus.

Genus OROPHOCRINUS, Von Seebach, 1864.

Orophocrinus, von Seebach, Nachr. k. Gesellsch. zu Göttingen, 1864, p. 110.

Codonites, Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1869, p. 84 (note); Meek and Worthen, Illinois Geol. Survey Report, 1873, v. p. 463.

Obs. Von Seebach was the first to point out the distinction of this generic type from that of the ordinary *Pentremites*; and although it received the name *Codonites* five years later, we feel bound to follow Ludwig and Zittel in using Von Seebach's name rather than that of the American authors. Both chose for their type the *Pentremites stelliformis*, Owen and Shumard.

The second description by Meek and Worthen is sufficiently explicit to make it unnecessary for us to redescribe the genus; we need only at present point out a few of its peculiarities, more especially in connexion with the European species.

But two species of *Orophocrinus* are at present known, both of them from the American Carboniferous series, viz.

T. Reinwardtii and *T. lineatus*; but the other species agree so well in form and outline with these, that we can hardly doubt their generic identity.

* Non *P. clavatus*, Schultze, Devonian, Eifel.

O. stelliformis, O. & S., sp., and *O. gracilis*, M. & W. In European rocks of corresponding age five species are now known to occur. There are two British Blastoids referable to this type, viz. *Pentremites inflatus*, Phillips, and *P. pentagonalis*, Miller, sp., whilst the other three are met with in the Carboniferous Limestone of Belgium—*Pentremites Puzos*, Münster, *P. Orbignyanus*, de Koninck, and *P. Waterhousianus*, de Kon. The first two of these are somewhat aberrant forms, presenting considerable differences from the American species, which approximate them to *Phanoschisma* and *Codaster*.

The gap, however, is bridged over so completely by *O. inflatus*, Phillips, sp., and *O. Waterhousianus*, de Kon., sp., that we have no choice but to refer them to this genus.

Orophocrinus differs from *Pentremites* proper, *Granatocrinus*, *Schizoblastus*, *Pentremitidea*, and probably also from *Troostocrinus* and *Tricalocrinus*, in the absence of marginal pores to the ambulacra and of circumoral spiracles. The place of these organs is taken by the ten elongated slits which run parallel or subparallel to the ambulacra. Further, the anal aperture of *Orophocrinus* is separate and distinct from these hydrospiral openings, having no connexion whatever with the latter, as is the case with the fifth or complex spiracle of the genera mentioned above. Lastly, the orals, in consequence of the absence of distinct spiracles, are imperforate. *Orophocrinus* thus possesses only one series of openings leading to the hydrospires, viz. the ten elongated slits bordering the ambulacra. The apparent difference in number between the latter and the five spiracles of a Pentremite is lessened when we recollect that in the last-named genus the spiracles are divided internally by a septum, whilst in *Schizoblastus* they are separately developed and correspond in number to the hydrospire-clefts of *Orophocrinus*.

In the widening of these clefts in the Belgian species, *O. puzos*, Münster, sp., and *O. Orbignyanus*, de Kon., sp., and the partial exposure of the hydrospire-slits, we see a foreshadowing of the conditions met with in *Phanoschisma* and *Codaster*. In both these genera there is likewise a separate anal aperture, whilst the anal interradius bears hydrospire-clefts in *Phanoschisma* and *Orophocrinus*, but not in *Codaster*.

A tendency towards the form of the true Pentremite is exhibited by one species in particular, the *O. gracilis*, M. & W.*; more than in any of the others. Although possessing the characteristic features of *Orophocrinus*, the upper portion of the calyx is much higher and less depressed than in the typical *O. stelliformis*. It also bridges over the gap between the American and European species; for not only are the hydro-

* *Loc. cit.* v. t. 8. f. 6.

spire-clefts in the latter much wider than in the former, but they are also contiguous to the ambulacra, without the intervention of a part of the radial plate.

D'Orbigny's *Dimorphocrinus** is undoubtedly congeneric with *Orophocrinus*. In the original definition it is said to have only two rows of plates; but de Koninck has since shown † that it was founded on *Platycrinites pentangularis*, Miller, which he considered a Pentremite deprived of its oral plates, whilst we hope to definitely show its relation to *Orophocrinus*.

We agree with the late Mr. Billings in regarding the structure of *Orophocrinus* as of more than generic importance when compared with that of other Blastoids; and we follow Meek and Worthen, as does Zittel, in regarding *Orophocrinus* as a Blastoid and not a Cystidean, as it was asserted to be by Billings ‡. He seems to have been led to this conclusion by the discovery of specimens with the peristome closed by minute plates, and by his peculiar views as to the mouth being confluent with the anal aperture. The absence of hydrospire-pores and spiracles we believe to be points of the greatest structural importance within the Blastoidea, but not sufficient in themselves to eliminate *Orophocrinus* from that class.

The oral plates, except in well-weathered specimens, are difficult to see, but are usually acutely arrowhead-shaped (*O. Waterhousianus*, *O. gracilis*, and *O. Orbignyanus*), or double diamond-shaped, with a constricted middle, as in *O. stelliformis*. The anal aperture is large, and either oval, as in the last-named species, or elongately and roundly triangular. In *O. stelliformis* it also has an outer raised margin; but we have not observed any tube or small proboscis as described in this form by Messrs. Wachsmuth and Springer §.

The ambulacra are linear in all but *O. Orbignyanus*, where they broaden out, and they possess only one groove, the food-groove, not three as in *Codaster*. We have not succeeded in detecting any sign of outer side plates, unless it be in *O. Orbignyanus*; but of this we cannot be sure. Meek and Worthen say they are unknown in *O. stelliformis*; but they appear to figure them in *O. gracilis*||. The length of the hydrospire-clefts is a variable character. They are shortest in *O. stelliformis*, but extend nearly the whole length of the ambulacra in *O. Waterhousianus* and *O. pentangularis*, and quite that in *O. inflatus* and *O. Orbignyanus*. As before stated, no true spiracles are present; but the clefts enlarge upwards towards

* Prodrome de Pal. 1849, i. p. 155.

† Rech. Crinoïdes Terr. Carb. Belgique, p. 194.

‡ American Journ. Sc. 1870, i. p. 234.

§ Revision, pt. 2.

|| Illinois Geol. Surv. Report, 1873, v. t. 8. f. 6.

the peristome and form a kind of spurious spiracle; this is particularly noticeable in *O. stelliformis*. The lancet-plate appears to be exposed in all the species in its upper part; but towards the distal extremity the side plates meet in the middle line and close over it, the amount of covered surface varying according to species.

The side plates are very numerous in *O. inflatus* and *O. pentangularis*; but the state of preservation of our specimens does not permit of the actual number being ascertained. *O. stelliformis* is said to possess fifty; and twenty-two exist in *O. gracilis*. There are at least twenty-five in *O. Waterhousianus*, and something under twenty in *O. Orbignyianus*. The hydrospires, so far as we are acquainted with them, vary from four to eight. There are five in *O. stelliformis*, from seven to eight in *O. inflatus* and *O. pentangularis*, and at least four in the two Belgian species.

We have not observed in either of the European species a plated peristome as described by Dr. C. A. White*; but we entertain little doubt that it existed in the perfect form.

The following are the species we refer to *Orophocrinus*:—

- Codonites gracilis*, M. & W. Burlington group (Subcarboniferous), Iowa.
- Pentremites inflatus*, Gilb. Carboniferous Limestone, England.
- P. Orbignyianus*, de Kon. Carboniferous Limestone; Belgium.
- Platyerinus pentangularis*, Miller. Carboniferous Limestone, England.
- Pentremites puzos*, Münster. Carboniferous Limestone, Belgium.
- Codonites stelliformis*, O. & S., sp. Burlington group (Subcarboniferous), Iowa &c.
- Pentremites Waterhousianus*, de Kon. Carboniferous Limestone, Belgium.

From the above list it will be seen that *Orophocrinus* is entirely confined to rocks of the Carboniferous period, occurring, however, in those of Britain, Belgium, and America. It thus has a wider geographical distribution than any of the other genera occurring in Britain, *Granatocrinus* being as yet unknown on the continent, while the *Pentremitidea* of Spain, the Eifel, and the American Devonian rocks does not occur in Britain; and *Phanoschisma* of England, Belgium, and Spain is but very doubtfully recognizable among the American Blastoids.

* Boston Journ. Nat. Hist. 1863, vii. p. 486.